CHAPTER 14

The Nature of

Getting Ready...

- Who or what holds speed records on Earth?
- How do police use radar equipment?
- What do you need to know in order to graph and calculate speed?
- How far will a vehicle keep travelling after you hit the brakes?

396 km/h, Oct 22, 1999, Salt Flats, Utah

Science Log

Think about a roller coaster ride. How do you know when you are going fast on a roller coaster? How do you know when you have slowed down?

Read the captions for the photographs shown on these two pages. Did you know that peregrine falcons can dive almost as fast as a speeding race car — and a lot faster than most vehicles can go?

Any object that is moving has speed. Some, such as a glacier that might move one metre per year, move very slowly. Others, like particles of light that move 300 000 000 metres per second, travel at great speed!

It is not always easy to judge speed, as you will learn in the Starting Point activity. Astronauts on a space shuttle might not feel like they are moving at all. Yet they are travelling about a thousand times faster than a person on a roller coaster at an amusement park.

You can see why a mathematical definition of speed and a way of measuring it are important. Human senses are not always accurate enough for safety.

The purpose of this chapter is to answer the question, "What is speed?"

You will use and analyze graphs, work with equations, and learn how one form of police technology that measures speed works. Finally, you will learn how speed affects the stopping distance of objects and how to adjust your driving to handle this.

Speed

350 km/h during a dive!

What You Will Learn

In this chapter you will learn:

- how police radar equipment works
- how to define "velocity"
- to design, produce, and analyze distance/time graphs
- to calculate velocity using a simple formula
- why drivers should leave at least a three-second distance between their vehicle and the one in front

Why It Is Important

- Have you heard that speed kills? One reason maximum speeds are set is to allow drivers enough reaction time to prevent collisions. Understanding true measures of speed and the effects of high speed will help you drive and react to traffic more safely.

Skills You Will Use

In this chapter you will

- design and carry out investigations about velocity
- analyze and interpret distance/time graphs
- make calculations involving velocity, time, and distance
- examine technology related to velocity
- investigate and determine safe following distances

Starting Point ACTIVITY

How Fast Is *Fast*?

What is the fastest speed you have ever experienced? Was it in a car or airplane? Was it on a bike or skateboard? Did you know how fast you were going? What were the clues that suggested you were travelling at a high speed?

What to Do

Discuss the following questions with your class or in a small group.

1. Have you ever travelled in an airplane and looked out the window? Did it seem like you were going fast, or nearly standing still?
2. What was the fastest experience you have had in your life? Describe how you knew you were travelling very fast.
3. For each of the following methods of travel, describe your own experience. Develop a group chart listing the cues that told you how fast you were travelling.
   - walking
   - running
   - skating
   - riding a bicycle
   - riding in a car
   - riding in a bus
   - riding in a small airplane
   - riding in a big airplane
4. Summarize your observations from question 3. What are the most common cues that someone or something is travelling very fast?

What Do You Think?

1. Do the analysis provided by your teacher.

14.1 Defining Velocity

READING Check

Define "velocity." What two factors are needed in order to determine velocity?

In the Starting Point activity, you might have said you knew you were going faster when you felt more wind on your face, or when you saw your surroundings going past faster. If you drive a car, you might have said you looked at the speedometer.

Car speedometers use the two factors scientists use to determine speed. These are distance and time.

- **Distance** is a change in position.
- Change in position occurs over a period of **time**.

In this unit, we will use the term velocity to mean speed. **Velocity** is the distance travelled during a specific time interval. For example, the maximum legal speed on some Alberta highways is 110 km/h. In towns, it is half that — 50 or 60 km/h.

Vehicles travelling at 100 km/h cover a distance of 100 km in one hour. Those going at 50 km/h cover half that distance in an hour.

Notice that all explanations of velocity include units — km/h for vehicles, perhaps m/s for an ant or snail.

As long as a description of velocity includes units, you can get a fairly good idea of how fast something is going. What units would you use to describe the velocities shown in Figures 14.1 to 14.4?

Figure 14.1

Figure 14.2

Table 14.1 Chart of Comparative Top Velocities

Object	Velocity (km/h)	Velocity (m/s)
light	1 080 000 000 km/h	300 000 000 m/s
space shuttle	28 000 km/h	7778 m/s
cheetah	115 km/h	32 m/s
antelope	88 km/h	24 m/s
black tuna	80 km/h	22 m/s
salmon	60 km/h	17 m/s
hawk moth	53 km/h	15 m/s
human	37 km/h	10 m/s
stegosaurus	7 km/h	2 m/s
garden slug	0.05 km/h	0.01 m/s

km/h = kilometres per hour
m/s = metres per second

Figure 14.3

Figure 14.4

DESIGN & DO

INVESTIGATION 14–A

SKILL CHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Discovering Velocity

A police radar gun quickly measures the distance that a car travels during a very short period of time. In this activity, you will develop a method similar to that used by a radar gun. Using this method, you will determine the velocity of an object from measurements of the distance the object travelled and the time it took to travel that distance.

For this activity, you can use *any* object that rolls.

Challenge

Design a set-up to calculate the velocity of a moving object. Your set-up should work over different time and distance intervals.

Safety Precautions

- Set up your materials in a safe place that has been cleared of any sharp objects.

Apparatus

object whose velocity you wish to study

stopwatch

measuring tape

Design Criteria

A. Choose a rolling object to study.

B. Decide what units to use for distance and time.

C. Work with a partner to design a system to
- move the object,
- measure distance, and
- measure time.

D. Make sure your system will work for more than one distance and more than one time interval.

Plan and Construct

1. One method is to mark off a desired distance and stop the timer when the object crosses that point. Another method is to set a certain time, after which you stop the object and measure how far it travelled. The choice you make will depend on what materials you use. Do at least three trials for each distance or time measurement.
2. Create a data table with columns for distance, time, and velocity.
3. Get your teacher's approval before starting.

Evaluate

1. After each trial, fill out the relevant section of the data table. Calculate velocity by dividing the distance by the time.
2. Did your object travel at the same velocity all the time?
3. Why do you think there might have been differences in velocity? Did you make any errors in calculating or in your experimental method?

Off the Wall

Scientists estimate the land speed of dinosaurs and many extinct animals. First they measure the distance between fossilized footprints. Then they compare those distances to that covered by existing animals of similar size and history. Using this method, scientists have calculated that Tyrannosaurus Rex likely travelled just a little slower than humans!

Calculating Velocity

Radar guns calculate velocity almost instantly. The radar gun shoots two laser beams at a vehicle, and then the beams bounce back to a sensor. The two beams are a certain period of time apart. The sensor judges the difference in position during that period of time. A little calculator in the radar gun finds the velocity from the distance and time measurements.

You can do this yourself using a simple formula.

$$\text{velocity} = \frac{\text{distance}}{\text{time}} \text{ or } v = \frac{d}{t}$$

d = distance in kilometres (km) or metres (m)

t = time in hours (h) or seconds (s)

v = velocity in km/h or m/s

Any time you know the distance an object has travelled and the time it has taken to cover the distance, you can calculate the object's average velocity over that period of time by simple division.

READING Check

How does a radar gun calculate a car's velocity?

Disc CONNECT

To work more with velocity, load the student CD-ROM onto your computer. Launch the **Velocity** applet and follow the instructions.

Math CONNECT

Using the Formula for Velocity

Use the following procedure for problems involving distance, velocity, and time:

1. List the information from the question. This is what you know. Place each piece of information beside the letter that represents it. (For example, t = 10 s)
2. Put a question mark beside the item you do not know. This is what you want to find out.
3. Write the formula.
4. Put the numbers you know into the formula.
5. Make the calculation.

Sample Problem 1

A cue ball travels two metres toward the 8-ball. If it takes one second for the cue ball to reach the 8-ball, how fast was it moving in m/s?

Steps in Solving It

1. What do you know?

d = 2 m

t = 1 s

v = ?

2. What do you want to find out?

How fast is the ball moving?

3. How do you find out?

$$v = \frac{d}{t}$$

$$v = \frac{2 \text{ m}}{1 \text{ s}}$$

4. Show the velocity as distance per time.

The velocity of the ball is 2 m/s.

Sample Problem 2

A snowboarder makes it down a 1000 m run in 60 seconds. What is her velocity?

Steps in Solving It

1. What do you know?

$d = 1000$ m

$t = 60$ s

$v = ?$

2. What do you want to find out?

How fast is the snowboarder moving?

3. How do you find out?

$v = \frac{d}{t}$

4. Show the velocity as distance per time.

$v = \frac{1000 \text{ m}}{60 \text{ s}}$ or 1000 m/60 s

5. Divide the time units into the distance units.

$v = \frac{1000 \text{ m}}{60 \text{ s}} = 17$ m/s

The snowboarder moves at approximately 17 m/s.

Solve These

Use the examples above to help you solve the following problems. Be sure to show all of your calculations.

1. It is 10 metres from the back of the pool hall to the front door. If you travel that distance in 30 seconds, how fast are you travelling in m/s?
2. In a long shot to finish the game, the cue ball is two metres from the 8-ball. It takes half a second (0.5 s) for the cue ball to travel that distance. What is its velocity?
3. To get home you drive 25 km in half an hour. At what velocity are you travelling?
4. At what velocity would you have to drive to travel 20 km in 15 minutes (1/4 h or 0.25 h)?

Check Your Understanding

1. How does increasing the distance affect the time if the velocity stays the same?
2. How would doubling the velocity while keeping distance the same affect time of travel?
3. Stacy drives 180 km in two hours. How fast is she travelling? Show your work.
4. Alan rides his skateboard from his house to school in two minutes (120 s). The school is only 800 metres from his house. How fast does he travel in m/s?

Key Terms

distance
time
velocity

14.2 Graphing Velocity

Figure 14.5

They say a picture is worth a thousand words. A graph is just that — a picture. It is difficult to make sense of a table full of numbers that show distance and time. If you plot these numbers into points on a graph, however, you can see all the information at once.

In this section, you will see and use different graphs involving velocity. These are called distance versus time graphs. For short, we will call them **distance/time graphs**. In distance/time graphs:

- Time is plotted on the *x*-axis.
- Distance is plotted on the *y*-axis.
- The line of best fit that joins the data points gives information about the velocity.

To see how this works, look at Figure 14.6, which shows the velocity of a lawnmower.

Distance/Time Graphs

In distance/time graphs like the one in Figure 14.6, the title

- describes the object being studied (lawnmower) and
- what **variables** (changing aspects of the investigation) were measured for the graph (distance and time).

The *x*-axis and *y*-axis show

- the units for each variable (Time, measured in seconds, is on the *x*-axis. Distance, measured in metres, is on the *y*-axis.)
- the *x*-axis shows the **manipulated variable**. It is the one variable that is changed by the researcher (in this case, time).
- the *y*-axis shows the **responding variable**. It is the variable that is measured by the researcher as it changes as a result of changes to the manipulated variable (in this case, the distance the lawnmower travelled during each time interval).

Finally, the slope of the line shows that the lawnmower is moving at a constant velocity.

Try This!

What kinds of graphs have you already used in science? How was each kind of graph used?

READING Check

What part of a distance/time graph tells about the velocity?

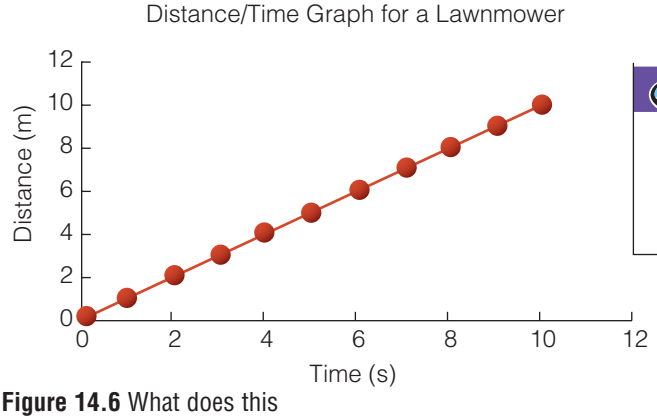


Figure 14.6 What does this graph show?

Computer CONNECT

Use a software program to make the distance/time graphs for the activities in this section.

Constant Velocity, Changing Velocity

Look at the two graphs on this page. In Figure 14.7, a straight line shows a constant velocity. A jagged or curved line, like the one shown in Figure 14.8, shows that the velocity of the object changed over time. The slope of the line shows the velocity of the object.

READING Check

During what time interval was the object travelling slowest in Figure 14.8? When was it travelling fastest?

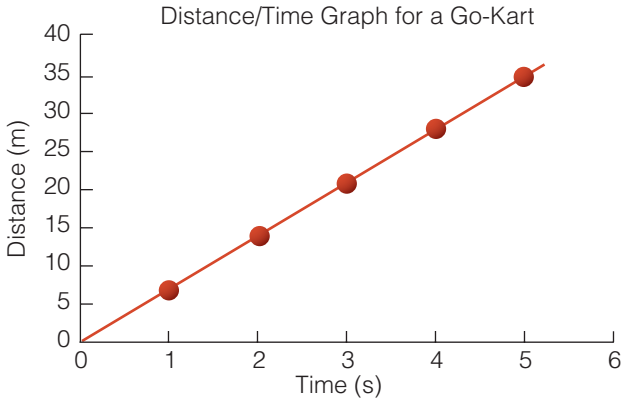


Figure 14.7 The straight line on this distance/time graph means that the vehicle was going at a constant velocity.

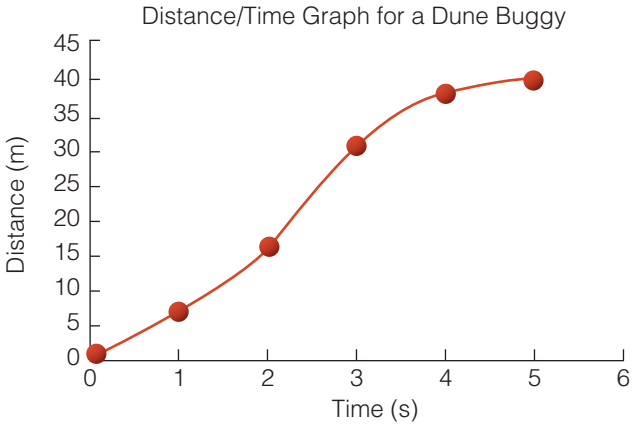


Figure 14.8 The curving line on this distance/time graph means that the vehicle was changing velocity.

Find Out ACTIVITY

What Are You Plotting?

The data here were collected by timing a running student for 10 seconds. Ten classmates stood along the track to mark the runner's position. A timer yelled at each second. The nearest classmate marked the runner's position.

What You Need

graph paper

ruler

pencil

What to Do

1. Look at the table of data shown here. Determine whether the position numbers change regularly or at different time intervals.

Position and Time Data	
Time (s)	Position (m)
1	5
2	10
3	15
4	20
5	25
6	30
7	35
8	40
9	45
10	50

2. Predict whether you think these data will result in a straight line.

SKILL CHECK

Initiating and Planning

Performing and Recording

Analyzing and Interpreting

Communication and Teamwork

3. Use the data to create a distance/time graph. Your graph should follow the same format as the one in Figure 14.7.

What Did You Find Out?

1. As time goes by, does the runner's position change regularly or in unpredictable ways?

2. Does the runner's velocity stay the same or change?

3. **(a)** Predict how the line would look if the runner's position changed by 6 m instead of 5 m during each time interval.
   (b) Redo the data chart showing these new data. Graph your new data.

4. Graph your data from Design & Do Investigation 14–A on page 253. How do distance/time graphs help you to determine velocity?

CONDUCT AN

INVESTIGATION 14–B

SKILL CHECK

Initiating and Planning

Performing and Recording

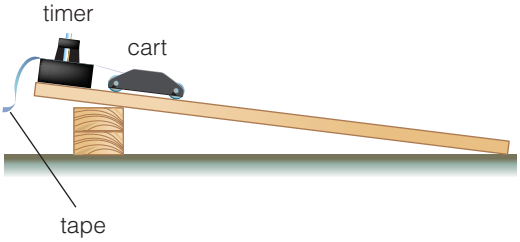
Analyzing and Interpreting

Communication and Teamwork

Graphing Motion

You now know:

- the definition for velocity;
- the fact that velocity is calculated by dividing distance by time; and
- a method for making a line graph.



In this activity, you will use this knowledge to create your own data table and distance/time graph based on a moving dynamics cart.

Dynamics carts are useful for investigating the relationships among velocity, distance, and time. A dynamics cart can be set off at approximately the same velocity each time if it is released from a stopped position at the top of a ramp. The movement of the cart after it reaches the flat floor can be measured using a ticker tape machine.

To use a ticker tape machine:

- Attach the ticker tape to a dynamics cart and feed the paper through the machine.
- When you turn the machine on, it will begin printing dots at regular time intervals. These dots will always be exactly the same time interval apart — for example, 1, 2, or 5 seconds.
- The distance between dots depends on the velocity of the cart.

The farther the dots are from one another, the farther the object is moving in the same time interval. That means that velocity is increasing. You can use the distance you measure on the tape, the time interval, and the formula for velocity to find the velocity of the cart.

$$\text{velocity} = \frac{\text{distance}}{\text{time}}$$

Problem

What is the velocity of a dynamics cart after racing down a ramp?

Prediction

Estimate how fast you think the cart will go.

Safety Precautions

- Make sure the pathway for the cart to run down is clear of obstacles. Do not release the cart unless all of your classmates are safely out of the way.

Apparatus

ramp
dynamics cart
ticker tape machine
ruler

Materials

graph paper
pencil
ticker tape

Do not measure between dots. Measure from P0 to P1, from P0 to P2, from P0 to P3, and so on.

Procedure

1. Assemble the ramp on the floor where the dynamics cart will have lots of room to run once it gets off the ramp.
2. Place the ticker tape machine at the top of the ramp. Attach the ticker tape to the cart and feed it through the ticker tape machine.
3. Choose the time interval you will use. Remember that the smaller the number you choose, the closer together the dots will be. For example, if you set the machine at 30 ms, the machine will put one dot on the paper every 30 milliseconds. (1 millisecond = 1/1000 or 0.001 s)
4. Release the cart from the ramp. Start the ticker tape machine when the cart hits level ground.
5. Examine the ticker tape and mark where the dots seem to be the same distance apart. Use the first dot in this series as position zero. Measure off 10 dots from there.
6. Using your measurements, create a data table similar to the one in the Find Out activity on p. 257.
7. Use the data to create a distance/time graph.

Computer CONNECT

Graphs can be constructed quickly with spreadsheet programs on your computer. Enter your data in columns, select the type of graph you want, and the computer draws it for you.

Analyze

1. Explain why the ticker tape machine is started on level ground, instead of as soon as the cart is released from the top of the ramp.
2. **(a)** Which is the manipulated variable in this activity? Explain how you know.

   (b) Identify the responding variable.

Conclude and Apply

3. The dots on the ticker tape may start off close together, spread out, and then end up close together again. Explain what has happened to the dynamics cart in order to create this pattern.

Extend Your Skills

4. If the machine were set to 50 ms, how many dots would you get per second?
5. See what happens to the velocity and the distance/time graph when masses are added to the chart.

READING Check

Define the terms "rise" and "run."

Calculating Velocity from a Distance/Time Graph

In Conduct an Investigation 14–B, you made distance/time graphs using data from a data table. You plotted each distance and each time as points or co-ordinates on your graph. You can use such a graph to determine the velocity of an object. The method is shown in the Math Connect below.

Before starting on the Math Connect, study Figures 14.9 and 14.10. Note that the **run** on a distance/time graph shows the time interval between two points. The **rise** shows the distance interval between the same two points.

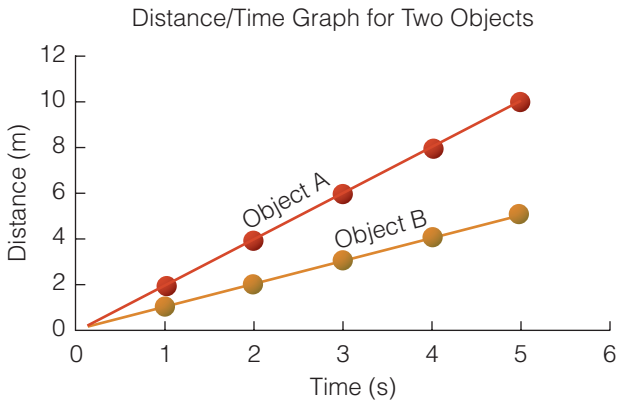


Figure 14.9 Both objects are moving at a constant velocity. Object A is moving faster than object B.

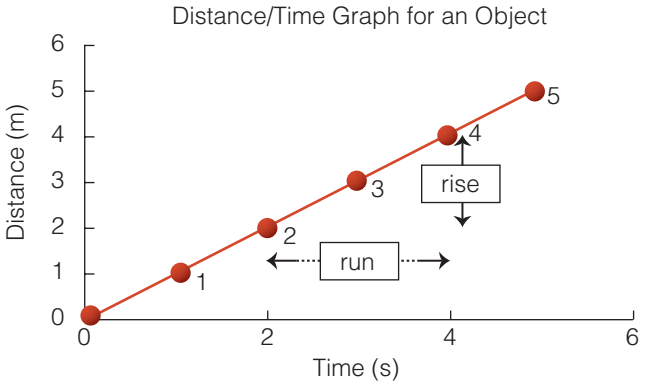


Figure 14.10 Identify the rise and run on this graph.

Math CONNECT

Slope Formula

The line on a distance/time graph represents the velocity of the object being studied. As you see in Figure 14.9, the steeper a line is, the faster the object is moving.

The steepness of the line is referred to as its **slope**. You can use the slope of a line to calculate exactly how fast an object is moving.

To find the slope:

1. Choose two points on the line. Identify the co-ordinates of the two points. For example, mark the number on the *x*- and *y*-axis for each point.
2. Find out the rise. This is the distance interval between the two points. To calculate the rise, find the difference between the two *y*-axis points.
3. Find out the run. This is the time interval between the two points. To calculate the run, find the difference between the two *x*-axis points.
4. To find the velocity, divide the calculation from Step 2 (rise) by the calculation from Step 3 (run).

$$v = \frac{\text{rise}}{\text{run}} \text{ or } \frac{\text{distance}}{\text{time}}$$

Sample Problem

What is the slope of the distance/time graph for Granny's car?

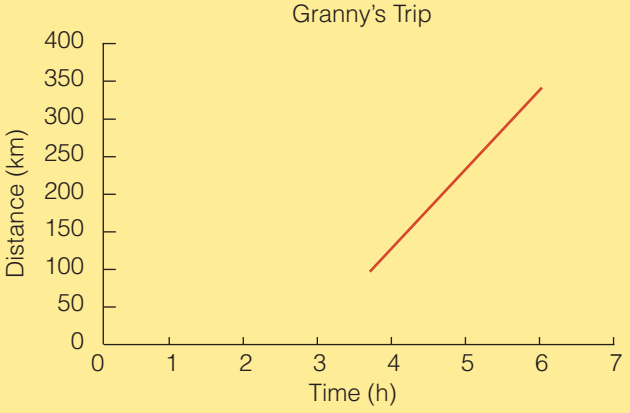


Figure A

Steps in Solving It

1. What do you know?

Two points on the graph are (100, 3.6) and (340, 6.0).

The distance units are in kilometres.

The time units are in hours.

2. What do you want to find out?

How fast is Granny travelling?

3. How do you find out?

i. How far did Granny travel?

Calculate how far Granny travelled between the two points on the graph (distance = points on the *x*-axis.)

$d = 340 \text{ km} - 100 \text{ km} = 240 \text{ km}$

ii. How long did it take Granny to travel this distance?

Calculate how long it took Granny to travel between these two points (time = points on the *y*-axis.) This will give you a time measurement.

$t = 6.0 \text{ h} - 3.6 \text{ h} = 2.4 \text{ h}$

iii. What do you know?

$d = 240 \text{ km}$

$t = 2.4 \text{ hr}$

$v = ?$

$$v = \frac{d}{t} = \frac{240 \text{ km}}{2.4 \text{ h}} = 100 \text{ km/h}$$

4. Show the velocity as distance per time.

Granny is travelling at 100 km/h.

Solve These

Use the example above to help you solve the following problems. Be sure to show all of your calculations.

1. Calculate the velocity of the go-kart by calculating the slope of the graph in Figure B. Show all your steps.

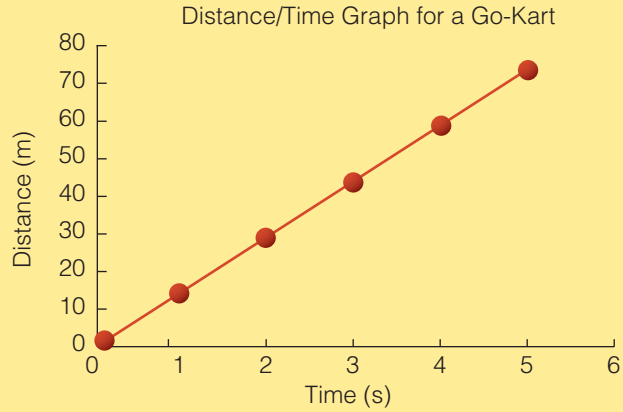


Figure B

2. Look back to the graph you made in Conduct an Investigation 14–B on page 258. Calculate the velocity of the dynamics cart by calculating the slope of the graph.

Check Your Understanding

1. What does the slope of a line on a distance/time graph represent?

2. What does the horizontal line on a distance/time graph represent?

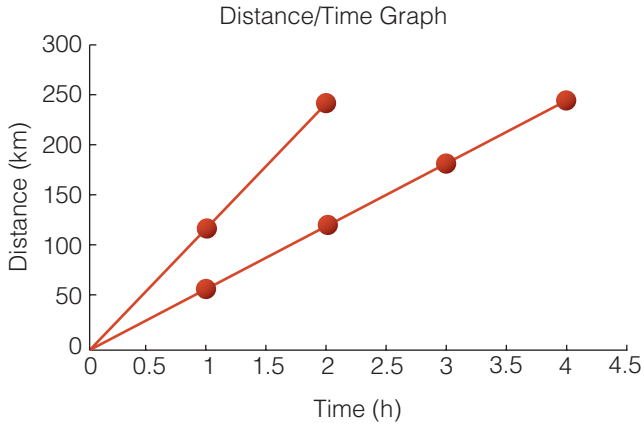
3. In a distance/time graph, which variable is manipulated? Which variable is responding?

4. (a) There are two lines on the distance/time graph shown here. One line is twice as long as the other. What does that represent?

(b) If the slope of one line is twice that of the other one, what does that suggest?

Key Terms

distance/time graphs	run
variables	rise
manipulated variable	slope
responding variable	



14.3 Calculating Distance

READING Check

How is the formula for distance related to the formula for velocity?

Before travelling to Europe, you calculated the number of kilometres you would travel directly east to reach your destination. During the flight, you learned that the actual flightpath took a shortcut by heading north. You learned the airspeed of the plane from the pilots, and spent the rest of your eight-hour flight calculating the length of the shortcut.

To find distance, you multiplied the velocity of the airplane times the amount of time you travelled at that velocity. The formula you used is distance = velocity × time.

Try This!

What unit do you get by dividing the unit for distance by the unit for time? What unit do you get by multiplying the unit for velocity by the unit for time?

Math CONNECT

Using a Distance/Time Graph to Calculate Distance Travelled

You now know how to calculate velocity by using a graph, or by dividing distance by time. The formula you use is $v = \frac{d}{t}$. As you learned in the Math Connect on page 260, the slope on a distance/time graph represents velocity.

How could you use the information on a distance/time graph to calculate the distance travelled?

If you knew the velocity (the slope of the graph) and the time (the run of the graph), you could multiply them to find the distance (the rise of the graph). You can find the distance an object has travelled by multiplying its velocity times the time it travelled.

$$d = vt$$

Sample Problem 1

You decide to get into shape for the football season by riding a stationary bike for 30 minutes (0.5 hours) each day. If you were pedalling at an average speed of 15 km/h, what would the odometer read at the end of one session?

Steps in Solving It

1. *What do you know?*
   time = 0.5 h
   velocity = 15 km/h
   distance = ?
   $d = vt$
2. *What do you want to find out?*
   How far you would have travelled.
3. *How do you find out?*
   $d = vt$
   = 15 km/h x 0.5 h
   = 7.5 km
4. *Summarize your findings.*
   You would have travelled 7.5 km.

Sample Problem 2

Your company asks you to travel from Leduc to Lethbridge in the summertime. You carefully keep to 100 km/h on the secondary highways, and subtract refreshment stops from your time record. When you reach Lethbridge, you calculate it has taken 4 hours and 15 minutes. This is 4.25 h. You are being paid by the km. How many km will your company have to pay you for?

Steps in Solving It

1. What do you know?

time = 4.25 h

velocity = 100 km/h

distance = ?

$d = vt$

2. What do you want to find out?

How far have you travelled?

3. How do you find out?

$d = vt$

$= 100 \text{ km/h} \times 4.25 \text{ h}$

$= 425 \text{ km}$

4. Summarize your findings.

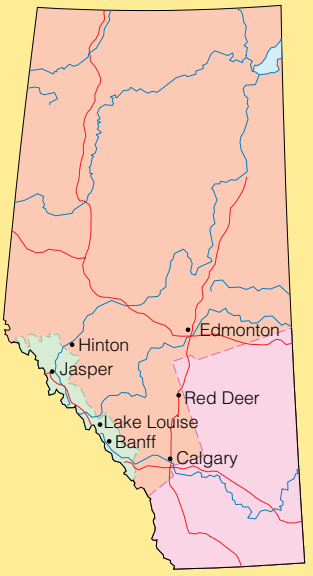
Your company will have to pay you for 450 km.

Solve These

Use the examples above to help you solve the following problems. Be sure to show all of your calculations.

1. What distance will you travel in 2.3 h at an average of 56 km/h?

2. Imagine you are going on a trip with many stops. Calculate and fill in the missing information for the Distance/Time Chart for Alberta.



Distance/Time Chart for Alberta

	Distance	Time	Speed
Edmonton–Red Deer		1.35 h	110 km/h
Red Deer–Calgary		1.33 h	110 km/h
Calgary–Banff	159 km	1.76 h	
Banff–Lake Louise	56 km	0.62 h	
Lake Louise–Jasper	289 km	3.2 h	
Jasper–Hinton		0.66 h	100 km/h
Hinton–Edmonton		2.48 h	110 km/h

Check Your Understanding

1. According to the average velocities shown in the log book, how far did the truck travel between 11:30 and 12:00?

2. According to the average velocities shown in the log book, how far did the truck travel between 6:00 A.M. and 7:30 A.M.?

3. A dog trots along behind a cowgirl's horse at 6 km/h. It takes the cowgirl three hours to get back to the ranch after checking the herd, but she takes half an hour of that time for a lunch break. How far did the dog trot?

Mountain Sky Transport

Daily Kilometre Log

06:00–09:30 clear roads, headed out from Edmonton for Hinton. Maintained 100 km/h with no stops clear through to Jasper.

09:30–10:15 had coffee while waiting to be unloaded

10:15–11:15 clear driving at 100 km/h

11:15–13:00 bad snowstorm, averaged 60 km/h

13:00–13:30 lunch stop

13:30–16:00 back to Edmonton, averaged 80 km/h

4. (a) If you travel 60 km/h for two hours, then an average of 30 km/h for half an hour, then 100 km/h for half an hour, how far have you travelled?

(b) Write a scenario to explain where you might have travelled at these velocities.

14.4 Distance Travelled during Reaction Time

READING Check

How do 30 km/h speed limits near schools and playgrounds help save the lives of children?

Why are speed limits different for different roads?

In a school or playground zone, there is a much greater chance that a child will jump into traffic. The 30 km/h speed limit is set to ensure that drivers will be able to stop fast enough to save the life of the child.

Do drivers' reaction times change with greater velocities? Probably not. However, the distance travelled during the time required to react will be much greater at higher velocities.

Imagine you were driving 80 km/h down a city street (with a normal limit of 50 km/h). If someone decided to run a red light at the intersection just in front of you, you would have no way of stopping in time.

DidYouKnow?

A car travelling at 50 km/h will travel 42 m in 3 s. At 120 km/h, the same car will travel 100 m in 3 s.

In Chapter 13, you found out your reaction time. In this section you will see how far a vehicle would travel during that reaction time before coming to a stop. When driving, reaction time is the time it takes between the driver seeing the need to stop and applying the brakes.

Try This!

Suppose your reaction time is around 0.25 seconds. Calculate the number of metres your vehicle travelling at 100 km/h will go in those 0.25 seconds before you even hit the brakes.

1 km = 1000 m, 1 h = 3600 s

READING Check

What needs to be added to the stopping distance to give a true picture of how far a vehicle will travel between the time you see a danger and the time the vehicle stops?

Reaction Time and Stopping Distance

Some driver education programs have new drivers do a simple exercise on a closed course. Student drivers drive around the course at 60 km/h. Then, on the signal from the instructor, they hit the brakes. What do you think happens?

The car will travel several metres before stopping. The distance that a vehicle travels after the driver applies the brakes is called the **braking distance**. **Stopping distance** includes the distance travelled during reaction time *plus* the braking distance.

What if you are reacting to a sudden obstacle in the road only 10 metres ahead of you? If you are going 60 km/h, it would be impossible to stop immediately.

Yellow traffic lights are set to last different lengths of time depending on the speed limit of the road. This is to make sure people have enough warning to see the light change, react, *and* stop their vehicle before the light turns red.

Table 14.2 Stopping Distance Based on Velocity

stopping distance = distance travelled during reaction time + braking distance

	Distance Travelled During Reaction Time		Braking Distance
Velocity	Distance Travelled between When Driver Sees Item and Realizes Must React (approximate)	Distance Travelled between Driver Recognizing Need to Respond and Applying Brakes (approximate)	Distance Travelled between When Brakes Applied and When Vehicle Stops (approximate)
32 km/h	6 m	6 m	6 m
48 km/h	9 m	9 m	12 m
64 km/h	12 m	12 m	22 m
80 km/h	15 m	15 m	35 m
96 km/h	18 m	18 m	50 m

Stopping distance includes the three measurements in this table.

1. Calculate the total stopping distance at each velocity by adding the data in each row.
2. Notice the difference between the stopping distance at 32 km/h and at 64 km/h. When the velocity doubles, how much does the stopping distance increase?

Following Distance

Cars that follow too closely behind others are at a high risk of having a collision.

No matter how fast your reaction time is, a vehicle takes a certain time and distance to stop. The faster it is moving, the longer it will take to stop.

For safety, you should keep a **following distance** of two seconds behind the car in front of you. This means that when the car in front of you passes a road sign, it should be two seconds before you pass the same sign.

Following too closely is against the law. The police can give you a ticket for tailgating.

Try This!

Follow a partner around the room closely and slowly. When your partner stops, try to stop without running into your partner. What two factors affect whether you run into each other, even if you have a very fast reaction time?

Check Your Understanding

1. What is the relationship between velocity and stopping distance?
2. What are two reasons for setting a yellow light to last longer?
3. Explain why drivers should adjust their following distance according to road and weather conditions.
4. If you were travelling 100 km/h in an area where the speed limit was 50 km/h, how would this affect your ability to react to what was going on in front of you? Explain.

Disc CONNECT

To learn more about reaction time and stopping distance, load the student CD-ROM onto your computer. Launch the **Stop That Car!** applet and follow the instructions.

READING Check

What is the recommended following distance? How do you check if you are keeping it properly?

DidYouKnow?

A car travelling at 50 km/h will take about 15 metres to stop. The same car travelling at 100 km/h will take at least 75 metres to stop.

Key Terms

braking distance
stopping distance
following distance

CHAPTER

14 Review

Key Terms

distance
time
velocity
distance/time graphs
variables
manipulated variable
responding variable
run
rise
slope
braking distance
stopping distance
following distance

Reviewing Key Terms

If you need to review, the section numbers show where these terms were introduced.

1. In your notebook, match each description in Column A with a term in Column B.

A	B
(a) a certain period of time to move a measured distance	i. velocity (14.1)
(b) the difference between two positions	ii. distance (14.1)
(c) how far your vehicle will go after you hit the brake	iii. stopping distance (14.4)
(d) the slope of this represents velocity	iv. following distance (14.4)
(e) measured in seconds or hours	v. distance/time graph (14.2)
(f) rise over run	vi. slope (14.2)
(g) calculated from distance divided by time	vii. time (14.1)
(h) the distance you will travel in 2 s is the length you should leave behind the car in front of you	viii. braking distance (14.4)
(i) reaction time *plus* braking distance	

2. In a distance/time graph for a rubber ball, distance is plotted on the *y*-axis and time is plotted on the *x*-axis. (14.2)
(a) Which variable is the one being manipulated?
(b) Which variable is responding?
(c) What does the slope of the line on the graph represent?
(d) What unit would you use to describe the slope of the line on the graph?

3. On a distance/time graph, does a steep line show a faster or slower velocity than a line that is not as steep? (14.2)

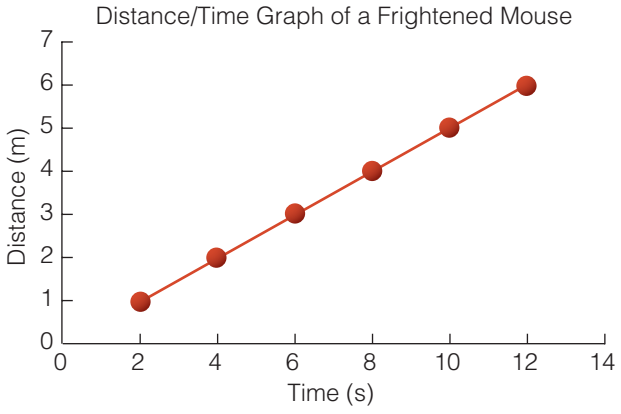
Understanding Key Ideas

Section numbers are provided if you need to review.

4. What formula describes how you can calculate distance if you know velocity and time? (14.3)

5. Use the slope formula below to calculate the velocity of the mouse described in this graph. (14.2)

$$v = \frac{\text{rise}}{\text{run}} \text{ or } \frac{\text{distance}}{\text{time}}$$



Developing Skills

6. You are going on a trip to visit your grandparents, 400 km away. (14.1)
- **(a)** If you have five hours to reach your destination, how fast will you have to travel in km/h?
- **(b)** What velocity would you want to maintain if you had six hours to travel 400 km?

Problem Solving/Applying

7. Which of the following will go farther, (a) or (b)? (14.3)
- **(a)** travelling 100 km/h for 4.5 hours
- **(b)** travelling 90 km/h for 6 hours

8. If an antelope runs 88 km/h for 10 minutes (0.166 hours) to escape a cheetah, how far will it travel? If the cheetah runs 115 km/h for 6 minutes (0.1 hours), can it catch the antelope? (14.3)

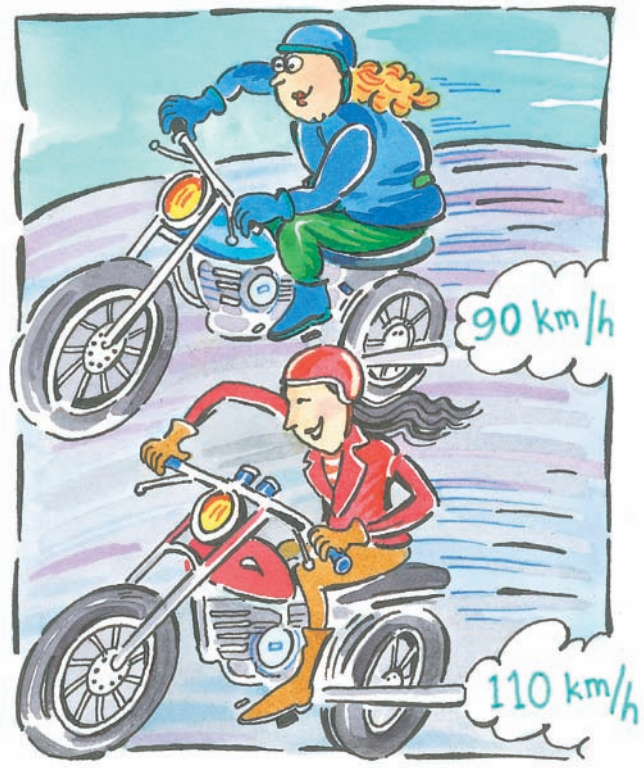
9. How far can a long-distance trucker travel in three 12-hour days if he travels an average of 90 km/h? (14.3)

10. A radar gun measures a car's velocity and calculates that it is travelling 0.050 km in 0.00042 h. How fast is the car going in km/h? (14.1)

11. Imagine you and your friend are both travelling to the same place, which is 250 km away. If she makes the trip in two hours, and you make it in three, what are your average velocities? (14.1)

Critical Thinking

12. Consider how far your vehicle goes at high velocities between the time you see a danger and can actually stop. Should speed limits on highways be reduced? Give two reasons to back up your answer. (14.4)



Pause & Reflect

1. Whether people are travelling across a city or halfway across the world, they want to get there faster.
- **(a)** How do you think technologists, scientists, and governments will meet this need while preserving the safety of individuals?
- **(b)** Can you think of any high-speed transportation methods that are being used around the world? Do you think any of those high-speed options will be used soon in Canada? Why or why not?

2. People's reaction time and eyesight change as they get older. Yet people usually get their licence in their teen years and have it indefinitely. Do you think there should be mandatory retesting of drivers? If so, how often? What should the tests involve? Explain your position.